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RESEARCH DEPARTMENT

PATTERN VISIBILITY IN TELEVISION CO-CHANNEL INTERFERENCE

Report No. T-091

(1962/26)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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SUMMARY

The dependence of the subjective visibility of the primary interference pattern upon offset and protection ratio is discussed. On the assumption that the inclination of the interference stripes does not affect the visibility of the pattern, it is suggested that offsets may be gathered into a number of groups, each group containing offsets giving rise to patterns of equal visibility. The relationship between the offsets within such groups is examined; in particular, the relationship between pairs of offsets, one having a frequency of the order of that of the line scan and giving rise to a pattern of horizontal stripes, and the other having a frequency greater than that of the line scan and producing a pattern of vertical stripes, is worked out in detail, with reference to displays conforming to the 405-, 625- and 819-line standards. The modifications to the wide-band protection ratios required when the wanted signal is an NTSC colour transmission are mentioned. Some aspects of the relationships involving offsets giving rise to diagonal stripes are then considered. The relationship between offsets giving rise to horizontal stripes on displays having differing field scan frequencies is also discussed, with particular reference to the American 525-line standard.

1. INTRODUCTION

When co-channel interference occurs between a television transmission and another signal, a pattern of stripes is superimposed on the displayed picture. The nature of this pattern (that is, the spacing between the stripes, their inclination relative to the picture, and their speed and direction of movement) depends primarily on the relationship between the frequency difference between the carriers of the wanted and interfering signals (the "offset") and the line- and field-scan frequencies of the wanted television signal.[1] The intensity of the pattern is governed primarily by the ratio of the e.m.f. of the wanted signal to that of the interfering signal at the input of the receiver. Both these factors are involved in determining the subjective visibility of the pattern, and experimental relationships can be obtained relating the two factors for a given subjective degree of pattern visibility.

If the interfering signal is unmodulated the interference pattern consists of equi-spaced stripes. Groups of offsets exist which give rise to patterns having the same spacing between the centre-lines of successive stripes along a line normal to them, and having the same speed of movement in this direction. Because the only difference between the patterns in these "equivalent groups" is the inclination of the stripes relative to the picture, which is a factor of small importance in deter-

mining the pattern visibility, it is reasonable to assume that they will all possess the same degree of visibility. The discussions contained in Sections 3 to 7 of this report are based on this assumption.

If the interfering signal is modulated, an interference pattern more complex than the simple primary pattern may be produced, and equivalent groups no longer exist. For this reason only unmodulated interfering signals are considered in this report. The results obtained in this way, however, are to a great extent applicable to the cases in which the interfering signal is modulated. This is because the carrier is always the largest component of an amplitude-modulated signal, and the complex patterns produced by the modulation components of the interfering signal predominate only when the primary pattern generated by the interaction of the two carriers assumes a structure of low visibility.

2. THE INTERFERENCE PATTERN

Before deriving relationships between the offsets in an equivalent group, the factors which determine the visibility of the interference pattern must be examined. In general, finer patterns are less visible than coarser ones, but if the spacing between the pattern stripes is progressively increased, the visibility reaches a broad maximum when the spacing is about one-tenth of the picture height and then decreases again as very coarse patterns are displayed.[2] It must also be remembered that although the effective ratio of the e.m.f.'s of the wanted and interfering signals is that existing at the input to the demodulator of the receiver, the ratio is measured at the receiver input. The effect of the receiver response must therefore be taken into account; if the offset is less than 40 kc/s this modification generally amounts to less than 0·5 dB.

As the frequency of the unmodulated interfering signal is swept through the pass-band of the receiver, the visibility of the pattern undergoes a slow overall variation, on which is superimposed a more rapid periodic fluctuation. This is shown diagrammatically in Fig.1(i). The rapid variations are entirely due to the changing structure of the pattern*; the overall variation is due to both the change in pattern structure and the modification of the amplitude of the interfering signal by the receiver response. The maxima of the periodic fluctuation shown in Fig.1(i) occur, for high offsets, when these offsets are integral multiples of the line-scan frequency, the patterns then consisting of a number of vertical stripes: other (high) offsets give rise to patterns consisting of inclined stripes which are less visible because of their finer structure. Detail of a typical maximum is shown in Fig. 1 (ii)(b). If, however, the offset is reduced, it eventually becomes so low that the number of vertical stripes produced at the integral line-frequency relationship is less than the number corresponding to the pattern of greatest visibility. This pattern will then occur at an offset sufficiently different from the integral-line value to produce the required stripe spacing, and will consist of a set of diagonal stripes. The shape of the maximum shown at (a) in Fig. 1(i) is therefore in reality as shown in Fig. 1(ii)(a).

The smallest acceptable ratio of the strength of the wanted signal to that of the interference is termed the "protection ratio". Because this quantity is a measure of the effect of the configuration of the pattern on its visibility, the

*see Section 7.2

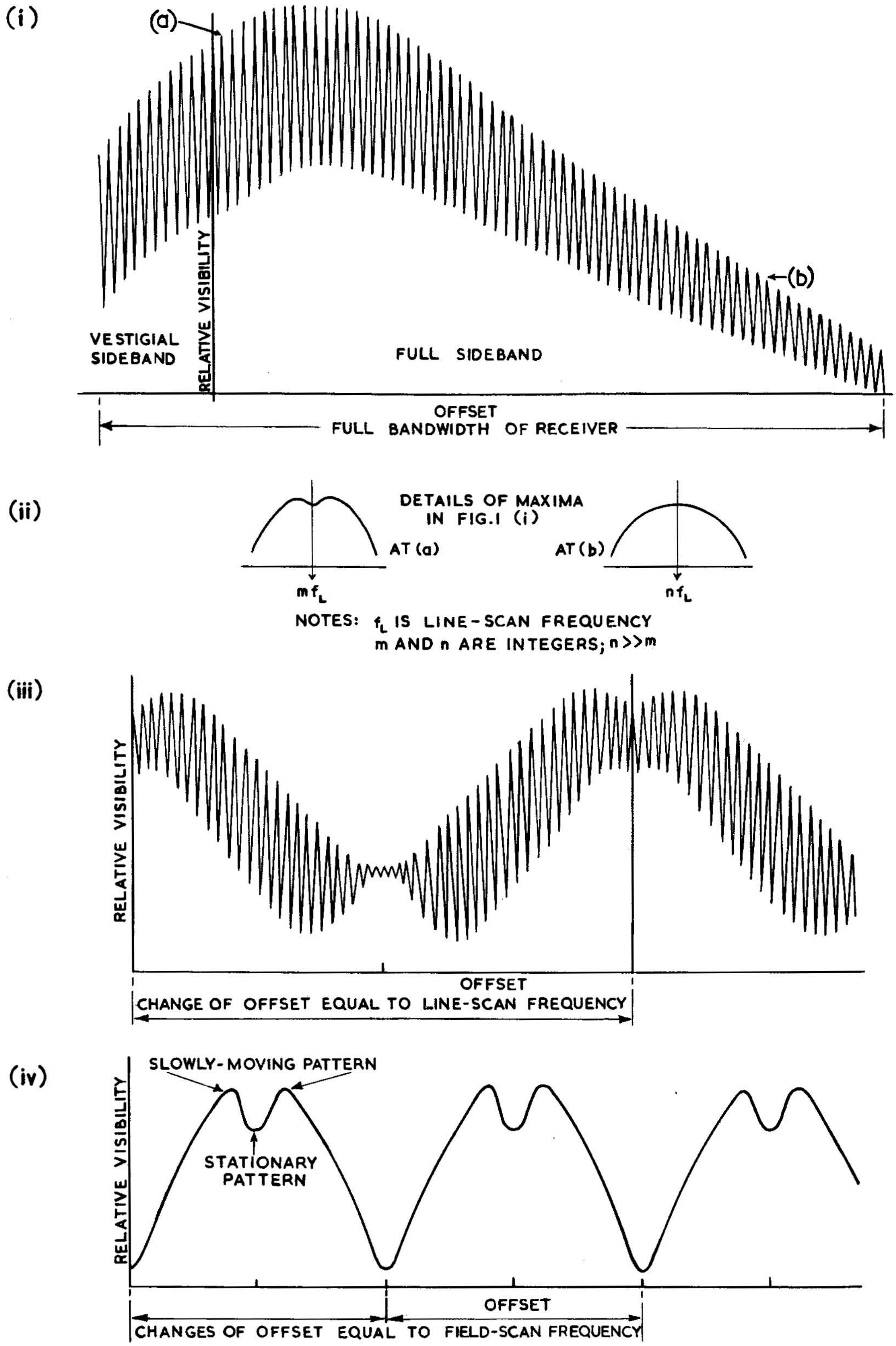

Fig. 1 - Relations between pattern visibility and offset

ordinates in Fig. 1 may be expressed in terms of it. The protection-ratio curve for high offsets assumes "worst pattern visibility" conditions and is therefore the curve joining all the maxima in Fig. 1(i).

Fig. 1(iii) shows one cycle of the periodic variation of Fig. 1(i) in greater detail. The cycle relates to a relatively low offset and the conditions of maximum pattern visibility (greatest protection ratio) therefore occur at an offset which is not an integral multiple of the line-scan frequency. It can also be seen that this curve is in turn composed of cycles of greater and less visibility, the periodic structure being related to the field-scan frequency. This structure, which is shown in greater detail in Fig. 1(iv), arises because the pattern visibility is related to the rapidity of movement of the pattern across the picture; slow-moving patterns are in general more visible than those that are stationary or rapidly moving. The frequency difference between successive offsets giving rise to stationary patterns is equal to the display field-scan frequency. The pattern is least visible for offsets midway between those producing stationary patterns. In this case the positions of the bright and dark bars are interchanged in successive fields and their subjective effect is partially cancelled by the integrating action of the eye, leaving only a flickering effect occurring at the picture frequency (half the field-scan frequency).

Offsets of the order of the line-scan frequency are of particular interest in the planning of television networks. These offsets are in the range covered by the first few cycles of relative visibility on each side of zero offset in Fig. 1(i). The inclination of the interference pattern bars with the horizontal is so small in these cases, except for offsets within about 500 c/s of the integral line-frequency values, that for practical purposes the bars may be taken as being horizontal (see Section 7.3). Curves relating the protection ratio to the offset can be obtained experimentally for these conditions, with a reasonable degree of precision. Because the successive cycles of the curves are very nearly identical, it is usual to describe them in terms of the lowest range of offsets that are encountered, that is, from values between zero and half the line-scan frequency. (In this connection it may be noted that in order to give greater clarity to the diagram, the frequency separation between the maxima of successive cycles in Fig. 1(i) has been greatly exaggerated.) As in the case of the high-offset curves, maximum pattern visibility conditions are assumed and the resulting curve is therefore the upper boundary of the envelope shown in Fig. 1(iii).

For descriptive convenience the range of offsets which gives rise to patterns consisting of horizontal stripes is in this report termed "close offsets", while other frequencies covering the remainder of the pass-band of the receiver are termed "wide offsets".

3. EQUIVALENT CLOSE AND WIDE OFFSETS FOR CONDITIONS OF MAXIMUM PATTERN VISIBILITY

In this section maximum pattern visibility is assumed to occur when the wide offset is nearly an integral multiple of the line-scan frequency. The interference pattern then consists of a set of vertical stripes moving slowly across the picture. A pair of equivalent close and wide offsets will therefore give rise to patterns having horizontal and vertical stripes respectively, but both having the same spacing between the stripes. The relationship between these two offsets will now be derived.

Consider first the close offset f, producing a pattern of horizontal stripes on the display. During one field scan the number of horizontal light (or dark) stripes will be:

$$n = \frac{f}{f_F} \tag{1}$$

where f_F is the field-scan frequency of the wanted signal. (For conditions of maximum pattern visibility n is very nearly an integer and the stripes move slowly up or down the picture.)

The distance between the centres of adjacent light (or dark) stripes is therefore:

$$d = \frac{h}{n}$$

$$= \frac{hf_F}{f}$$

$$= \frac{V_F}{f} \tag{2}$$

where h is the picture height, including the field blanking interval and assuming that the scan flyback occupies zero time,

and V_F is the vertical component of the velocity of the scanning spot.

Now consider the wide offset F, producing a pattern of vertical stripes. During one line scan the number of these vertical light (or dark) stripes will be

$$N = \frac{F}{f_L} \tag{3}$$

where f_L is the line-scan frequency of the wanted signal.
(N is very nearly an integer, so that the stripes move slowly across the picture, again giving conditions of maximum pattern visibility.)

The distance between the centres of adjacent light (or dark) stripes is therefore:

$$D = \frac{w}{N}$$

$$= \frac{wf_L}{F}$$

$$= \frac{V_L}{F} \tag{4}$$

where w is the picture width, including the line blanking interval, and again assuming that the flyback occurs instantaneously,

and V_L is the horizontal component of the velocity of the scanning spot.

Because of the assumption that the visibility of a pattern is not dependent on the inclination of its stripes relative to the picture (see Section 1) the stripe spacings of the two patterns under consideration may be equated for equal pattern visibility, i.e., $d = D$

hence $$\frac{V_F}{f} = \frac{V_L}{F}$$ (from Equations (2) and (4))

therefore $$\frac{F}{f} = \frac{V_L}{V_F}$$

The right-hand side of this expression is a constant for a given standard and may be termed the "equivalence constant" E,

hence $$F = E.f \qquad (5)$$

It is clear that the value of E depends on the "aspect ratio" of the scanning raster, including the line and field blanking intervals. If the aspect ratio of the displayed picture is adjusted to be equal to 4/3, then the "aspect ratio" of the scanning raster is very nearly 3/2 for all usual display standards. Table 1 shows values of E (to the nearest integer) assuming this ratio to be 3/2.

Table 1 Equivalence Constants

Standard	Equivalence Constant
405	304
625	469
819	614

4. DERIVATION OF A WIDE-OFFSET PROTECTION-RATIO CURVE FROM CLOSE-OFFSET MEASUREMENTS FOR A MONOCHROME TELEVISION TRANSMISSION

Because maximum pattern visibility conditions are assumed in both the close-offset and wide-offset protection-ratio curves, equation (5) enables the results of measurements taken under one offset system to be extended to include the other offset system. The derivation of wide-offset protection-ratio curves from close-offset measurements will now be described.

The experimental curves[3] relating protection ratio to close offset were obtained using 405-line, 625-line and 819-line displays, each having a field-scan frequency of 50 c/s. These curves are shown in Fig. 2. It can be seen that the curves are all of the form indicated by the upper boundary of the envelope shown in Fig. 1(iii), each having a minimum at a frequency equal to half the line-scan frequency of the display standard.

It will also be noticed that the curves for all three display standards are coincident up to an offset of about 4 kc/s. For higher offsets, the rate of change of the 405-line protection-ratio curve decreases as the interference pattern

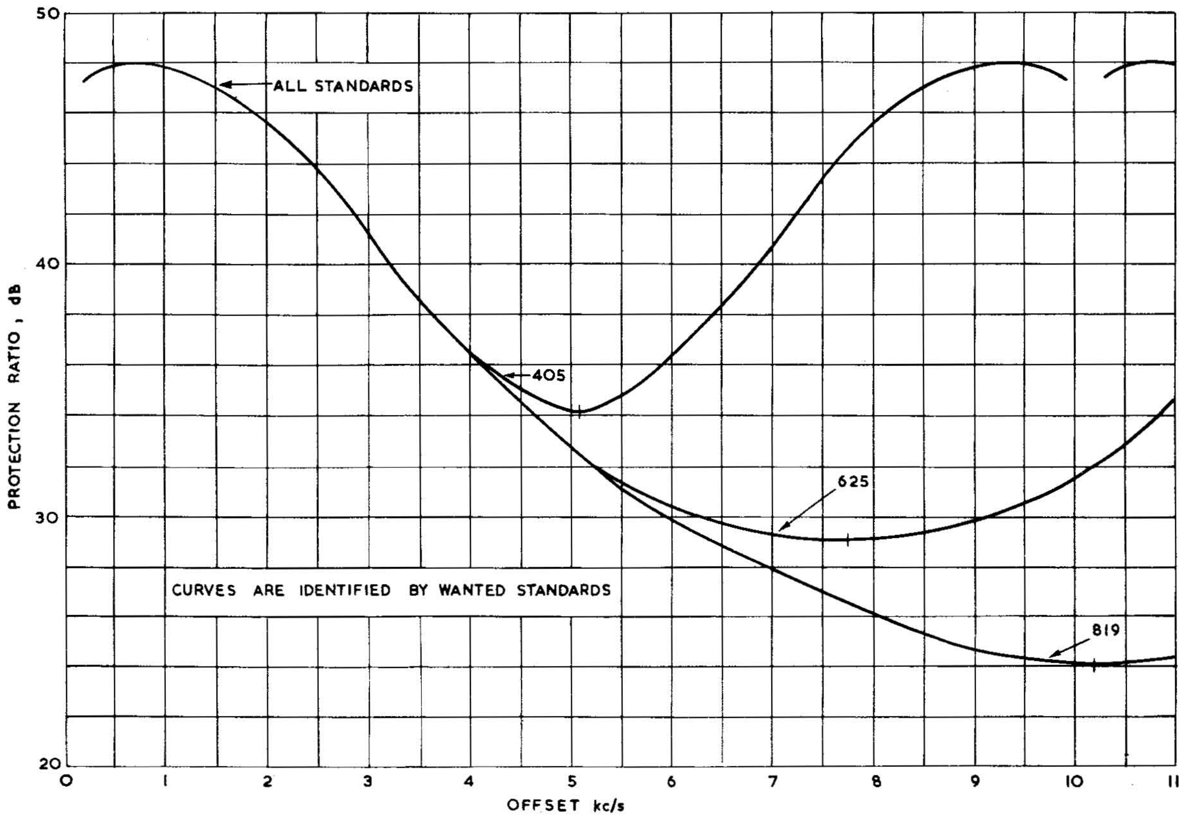

Fig. 2 - Experimental curves of close-offset protection ratios

spacing decreases and becomes comparable with the display line structure, until the minimum is reached at half the line-scan frequency, which is approximately 5 kc/s. A similar effect occurs at a frequency of 5·3 kc/s, when the curves for the 625-line and 819-line displays diverge.

Up to the frequency of 5·3 kc/s the fact that the protection ratio for a given frequency is the same for more than one display standard indicates that the only factor involved is the configuration of the interference pattern. Above this frequency, however, the value of protection ratio may not have been determined solely by the configuration of the interference pattern, but may have been influenced by the relation between the pattern spacing and the display line-structure. This frequency therefore represents the limit beyond which the close-offset curve may not safely be used to derive a corresponding wide-offset relationship.

The curve obtained by multiplying the frequency scale of the close-offset curve by the equivalence constant may be called the equivalent wide-offset curve. Fig. 3 shows this curve for the case of a 405-line display. It should be noted that this curve consists of two branches (A B C and A'B'C'), because it applies to interfering signals both higher and lower than the carrier of the wanted transmission. Two modifications are necessary to convert it into a practical wide-offset protection-ratio curve; these will now be described for the case of a 405-line transmission. The principle for the other standards is identical except for the difference in frequency scale.

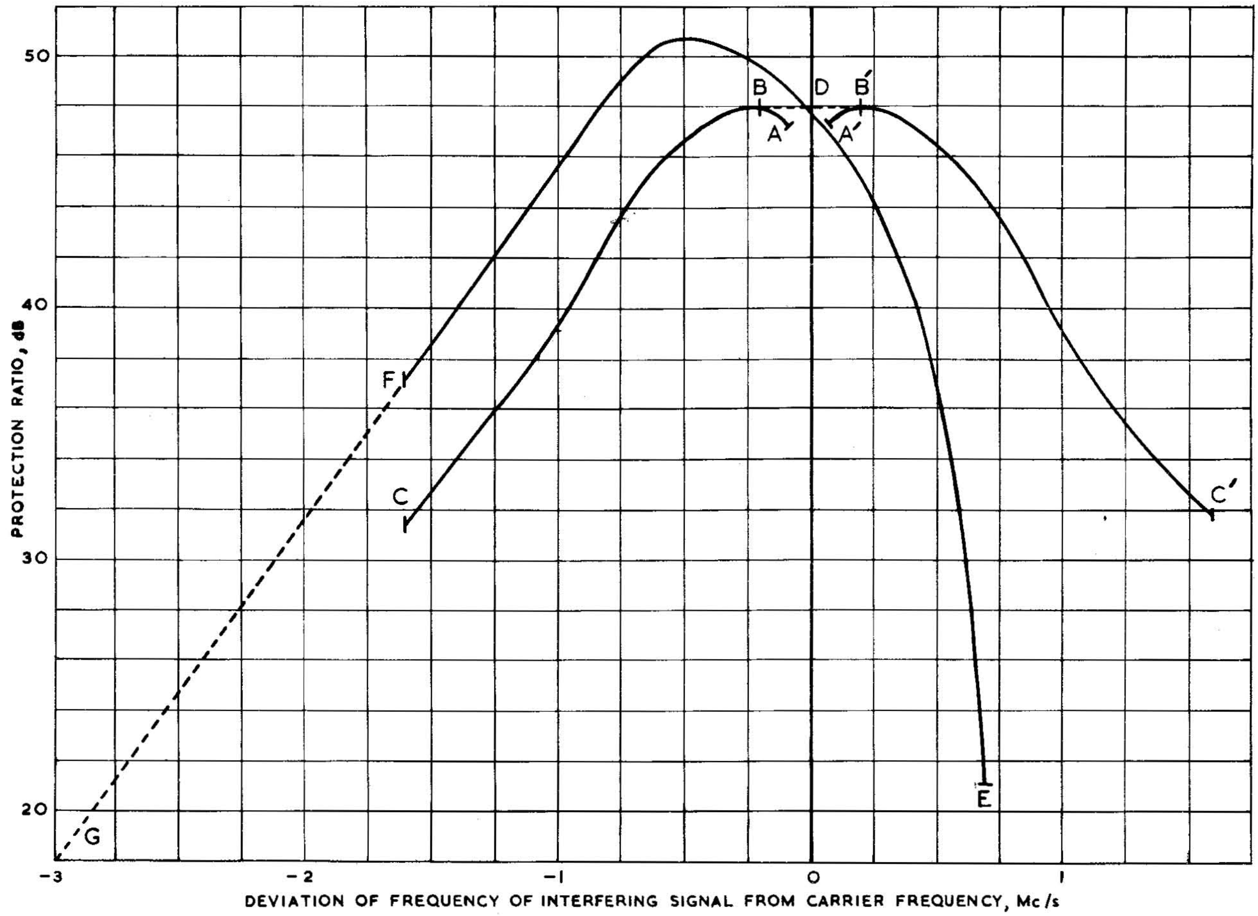

Fig. 3 - Derivation of the 405-line wide-offset curve

The maximum occurring in the close-offset curve has been reproduced in the equivalent wide-offset curve (B and B' in Fig. 3). The reason for the occurrence of this maximum in the case of close offsets has been mentioned in Section 2. Because this explanation does not apply to the wide-offset curve, which is concerned only with maximum-visibility conditions in the vicinity of a nominal offset, the maximum value of protection ratio must be assigned to all the frequencies lying between the points B and B'. The equivalent wide-offset curve is therefore modified by joining the points B and B' by a straight line (B D B' in Fig. 3).

A further and more important modification is produced by the effect of the receiver response. The "ideal" characteristic of a 405-line receiver is shown in Fig. 4. In the case of close offsets the wanted carrier and the interfering signal are both affected by the receiver response to the same extent, but for wide offsets it can be seen that the interference will be enhanced relative to the carrier if its frequency decreases, and reduced if its frequency increases. Appropriate modifications may therefore be made to the curve C B D B'C' in Fig. 3 to give the curve E D F.

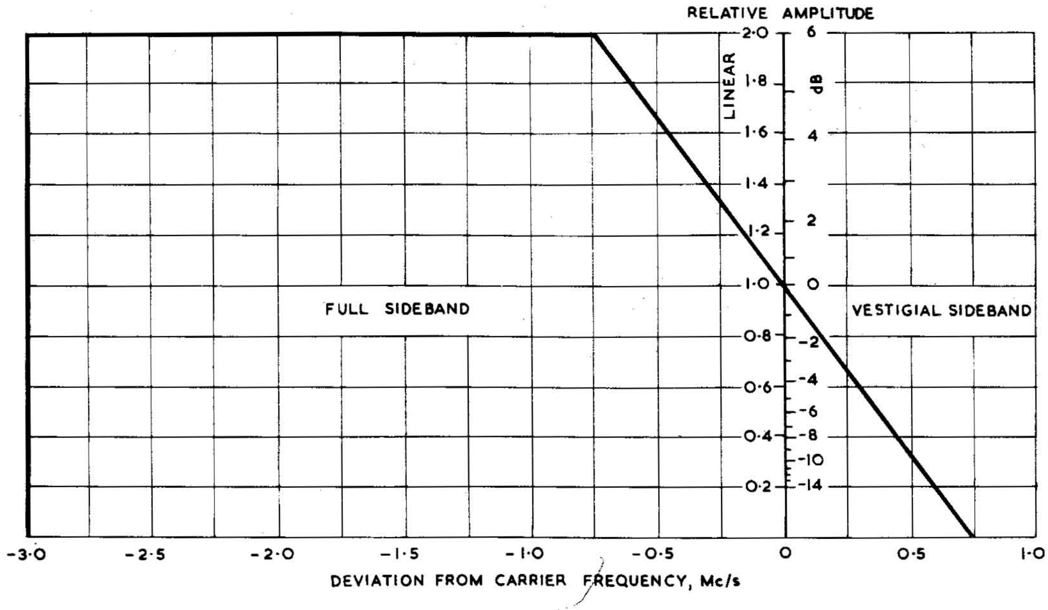

Fig. 4 - Ideal response of a 405-line receiver

No experimental evidence is available from the close-offset curves for the value of protection ratio required for wide offsets greater than that represented by the point F. Because the rate of change of slope of the curve in the region of the point F is very small, however, it seems reasonable to extrapolate the curve by means of a straight line tangential to the curve at F. This extrapolation is shown by the broken line F G.

The curve E D F G is thus the complete curve for wide-offset protection ratios for a 405-line monochrome television system. Similar curves may be derived for 625-line and 819-line systems.

For very large offsets it has been found experimentally[3] that there is an upper limit to the amount of interference than can be tolerated. High levels of interfering signal can affect the a.g.c. circuits of the receiver, causing objectionable variations in the brightness and contrast of the displayed picture. These limits are indicated in Fig. 5, which shows the derived wide-offset curves for the 405-line, 625-line and 819-line standards.

5. INTERFERENCE WITH A COLOUR TELEVISION TRANSMISSION

The effect of an interfering signal on a colour transmission of the NTSC type is to modulate the received colour carrier in phase and amplitude, as well as to produce the usual interference pattern. A second set of interference-pattern stripes is therefore produced, the configuration of the stripes being determined by the difference in frequency between the interfering signal and the colour carrier. On a colour receiver the variations in the colour carrier phase and amplitude make the additional pattern consist of sets of stripes of different colours. On a monochrome display, rectification of the amplitude changes of the colour carrier by the

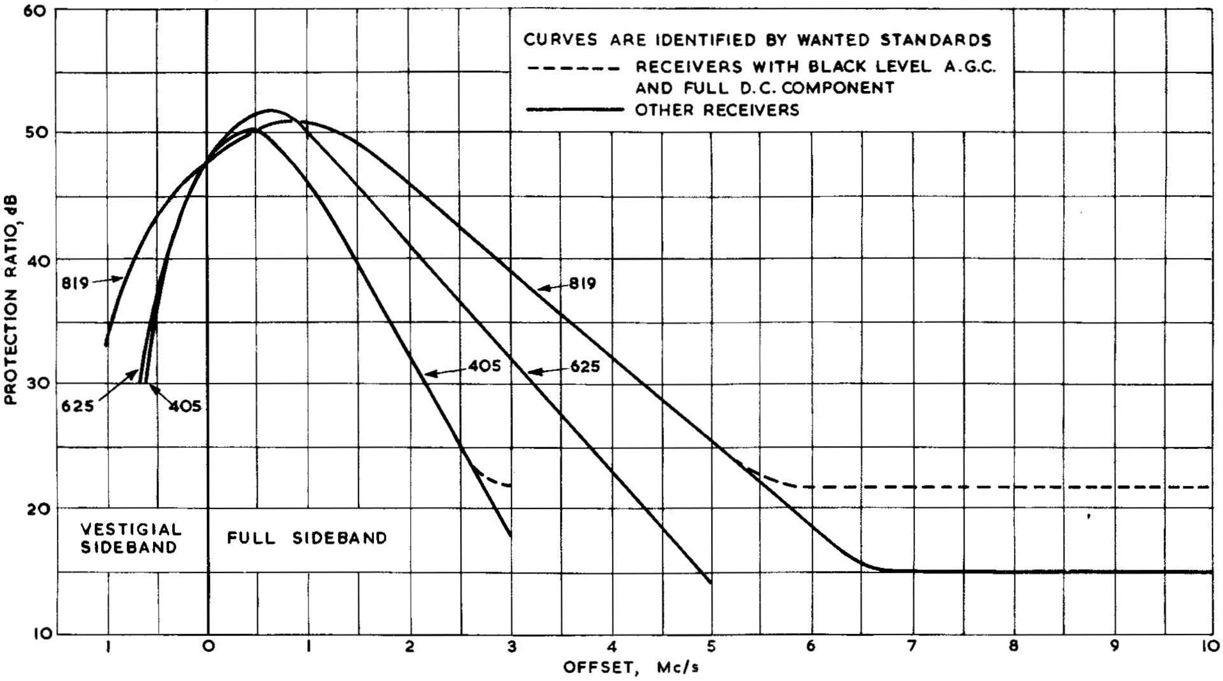

Fig. 5 - Derived wide-offset protection ratios for receivers having "ideal" response

non-linear characteristics of the receiver[4] gives rise to a version of the additional pattern consisting of light and dark stripes. Although the intensity of the pattern depends in both cases on the amplitude of the colour carrier as well as on that of the interfering signal, this relationship is more pronounced in the case of monochrome reception. Because of this relationship the pattern visibility is a function of the picture content of the wanted transmission. The protection-ratio curves which are shown in Fig. 5 must be modified to take account of this additional pattern. In the case of a 405-line colour transmission this modification has been determined experimentally,[5] and is shown in Fig. 6.

6. COMPARISON OF DERIVED PROTECTION RATIOS WITH EXPERIMENTAL RESULTS

Three groups of tests were carried out to compare the derived protection-ratio curves with directly-obtained experimental results: in all these tests, C.W. interfering signals were used.

a) Three monochrome receivers, one for each display standard, were viewed simultaneously. Each was supplied with wanted and interfering signals. The protection ratio of the signals supplied to the 405-line receiver was set to the value given by the appropriate curve in Fig. 5 for the offset under consideration, and the ratios of the interfering to the wanted signals supplied to the other two receivers were then adjusted until the interference patterns were equally visible on all three receivers. Two offset conditions were used. In the first, the same offset was applied to all three receivers, while in the second the offsets were adjusted to produce "equivalent-group" patterns, having the same spacing between successive stripes, on each display. Table 2 shows the results of these tests compared with the values obtained from the curves in Fig. 5.

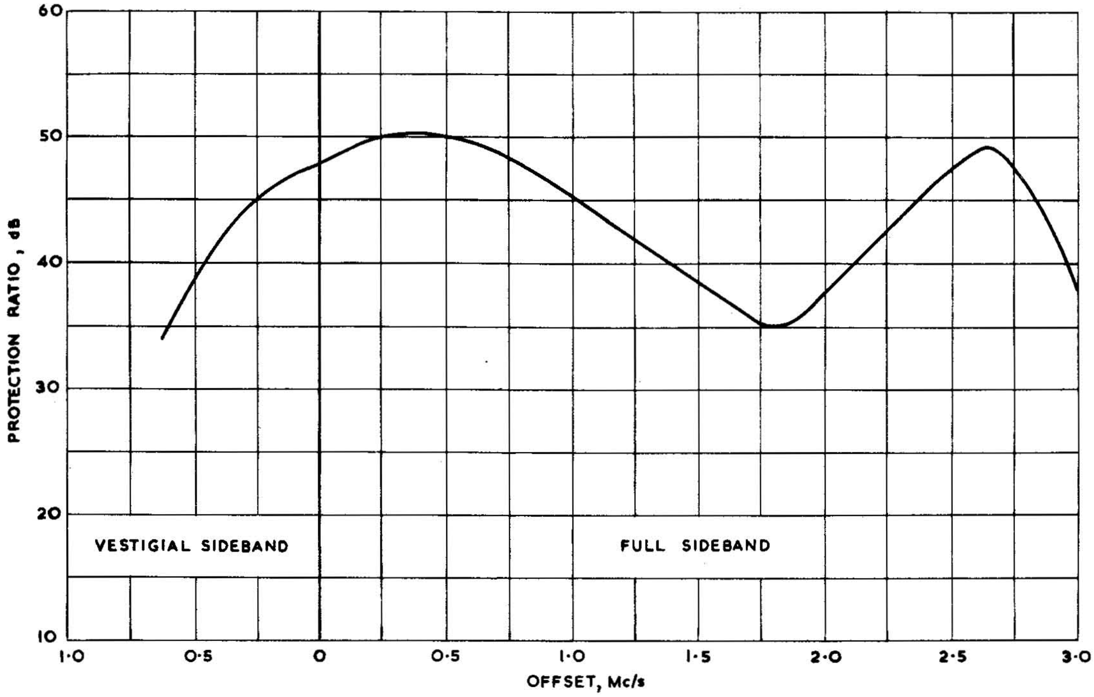

Fig. 6 - Protection ratios for C.W. Interference to a 405-line colour transmission

Table 2 - Comparison of interference patterns

SIDEBAND	OFFSET(S) FOR INDICATED DISPLAY	THE RATIO $\frac{\text{PROTECTION RATIO FOR INDICATED DISPLAY}}{\text{PROTECTION RATIO FOR 405-LINE DISPLAY}}$ FOR CONDITIONS SHOWN AT HEAD OF COLUMN (dB)					
		625-line display			819-line display		
		Test Result*	Theoretical (From Fig. 5)	Test Result *minus* Theoretical	Test Result*	Theoretical (From Fig. 5)	Test Result *minus* Theoretical
Full	200 Kc/s - all	0	+1	-1	+1	+1	0
Full	500 Kc/s - all	+4	+2	+2	+1	0	+1
Full	1 Mc/s - all	+3	+4	-1	+5	+5	0
Full	1·5 Mc/s - all	+8	+6	+2	+11	+10	+1
Full	2 Mc/s - all	+7	+9	-2	+10	+14	-4
Full	500 Kc/s - 405 750 Kc/s - 625 1 Mc/s - 819	+3	+2	+1	0	+1	-1
Full	2 Mc/s - 405 3 Mc/s - 625 4 Mc/s - 819	+2	0	+2	-2	0	-2
Vestigial	500 Kc/s - all	+3	-1	+4	+9	+6	+3
	Mean			+0·9			-0·2

* Standard Deviation of Test Results ≅ 2 dB.

b) An assessment of the protection ratio required for a 405-line monochrome transmission was made at several frequencies covering the whole of the receiver pass-band, using the same experimental technique as that employed for obtaining the close-offset curves.[3] These results are compared with the derived curve in Fig. 7.

c) Using a 405-line NTSC-type colour signal as the wanted transmission, protection-ratio measurements were made at offsets having values relatively near to the main carrier of the transmission, and also at offsets such that the frequency of the interfering signal differed from that of the colour carrier of the transmission by the same values. Both colour and monochrome receivers were used. The ratio of the value of protection ratio obtained for each offset relative to the colour carrier to that required for the same offset relative to the main carrier are compared in Fig. 8 with the values expected from the curve shown in Fig. 6.

In Table 2 and Figs. 7 and 8 the experimental results have been corrected to allow for the departure of the responses of the receivers from the "ideal" characteristic.

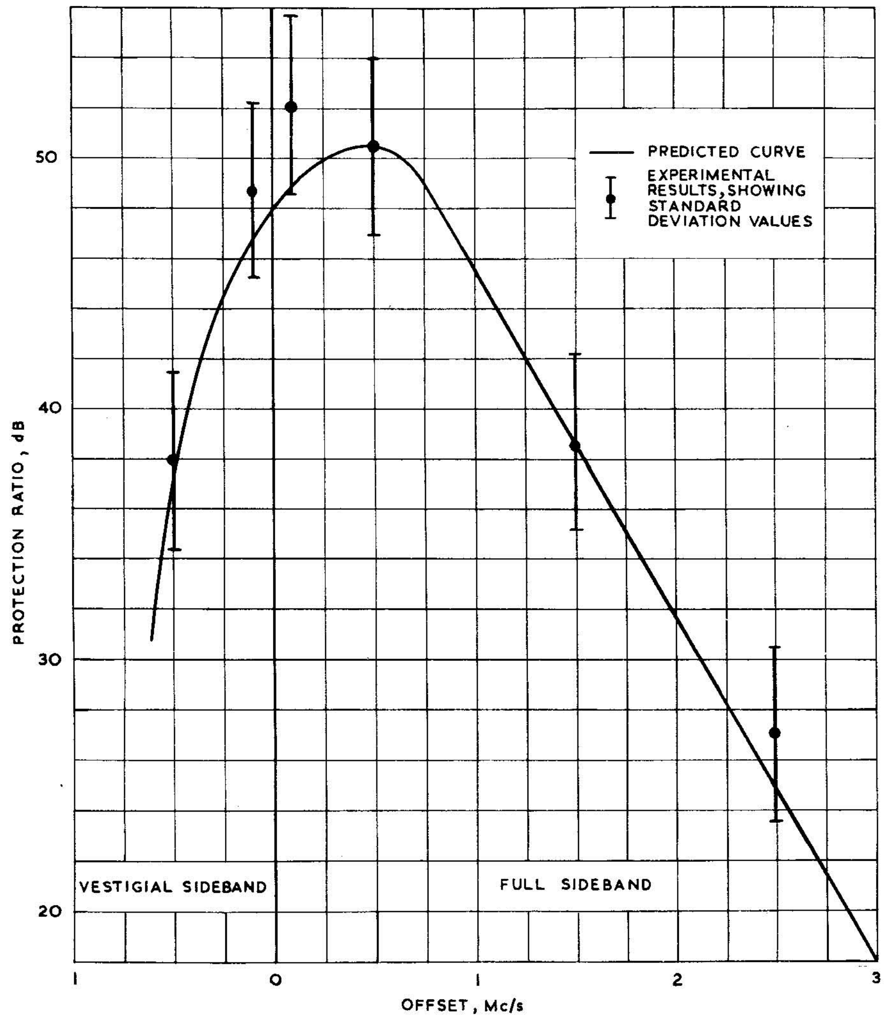

Fig. 7 - Comparison between derived curve and experimental results in the case of a 405-line monochrome signal

It must also be remembered that although very accurate control of the offset was possible in the case of the close-offset measurements, the experimental arrangements were such that when wide offsets were used this control was much less precise. The very stable close offsets gave rise to patterns consisting of stripes moving at a constant speed relative to the picture; in the case of the measurements from which the curves shown in Fig. 2 were constructed this speed was adjusted to give conditions of maximum pattern visibility. On the other hand, the less stable wide offsets produced patterns consisting of stripes whose speed of movement varied with time in a random manner: the results of the wide-offset measurements shown in Table 2 and Figs. 7 and 8 were obtained with such patterns. The effect of the resulting continual variation in pattern visibility on the protection ratio value was determined in a separate experiment and has also been allowed for in Table 2 and Figs. 7 and 8: the large standard deviation of the experimental results may also be attributed to this effect, because it was very difficult for an observer to assign

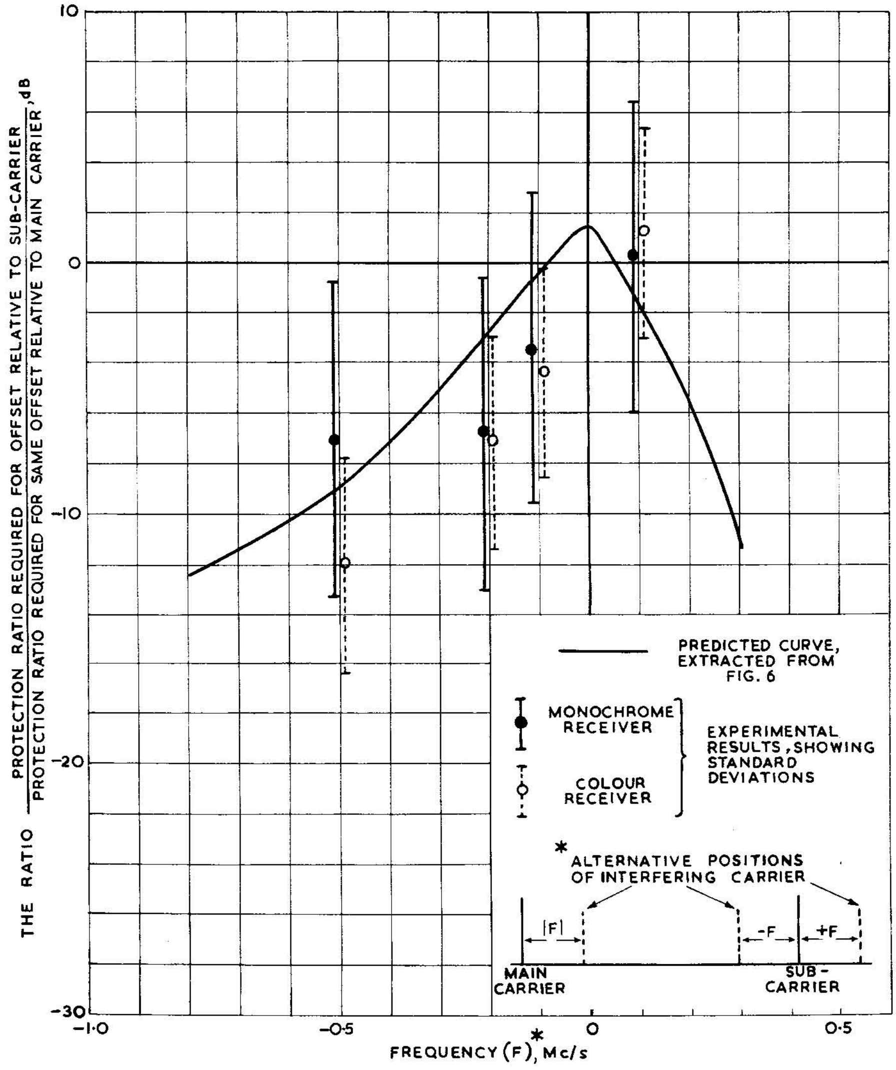

Fig. 8 - Difference in protection ratio required for offset near the sub-carrier of a 405-line colour transmission relative to that required near main carrier

a value of protection ratio to a pattern whose visibility was continually changing. The greater standard deviation of the results obtained with a monochrome receiver relative to those obtained with a colour receiver shown in Fig. 8 was produced by the more pronounced dependence of the visibility of the interference pattern on the picture content when the monochrome receiver was used, as mentioned in Section 5.

Table 2 and Figs. 7 and 8 show that within the limits imposed by the experimental accuracy, the measured values agree with the curves for monochrome and colour transmissions shown in Figs. 5 and 6. The extension of the close-offset results to include the wide-offset case is, in fact, a useful method of obtaining information on the latter condition with a greater degree of precision than can easily be achieved by direct experiment.

7. SOME THEORETICAL ASPECTS OF GENERAL OFFSETS

7.1. The Inclination of the Pattern Stripes

If the offset is not an integral multiple of the line-scan frequency, the interference pattern consists of a set of stripes running diagonally across the picture.[1] The offset may be expressed as:

$$F = mf_L + \delta F \quad ; \quad \frac{-f_L}{2} \leqslant \delta F \leqslant \frac{f_L}{2} \tag{6}$$

where m is an integer and δF is the difference in frequency between the offset and the nearest (m^{th}) harmonic of the line-scan frequency.

The inclination of the stripes with the picture vertical may be derived in terms of F and δF by considering the sideways displacement of the stripes on successive lines in one field. The distance between the centres of adjacent stripes along a scanning line is, from Equation (4), Section 3:

$$D = \frac{V_L}{F}$$

The sideways displacement of the stripes on successive lines of one field is therefore:

$$\delta D = \frac{V_L}{F} \cdot \frac{\delta F}{f_L}$$

Successive lines of one field are separated by a distance $\delta h = V_F/f_L$

If the inclination of the stripes to the picture vertical is ϕ, then

$$\tan\phi = \frac{\delta D}{\delta h} = \frac{V_L}{V_F} \cdot \frac{\delta F}{F}$$

$$= E \cdot \frac{\delta F}{F} \tag{7}$$

where E is the equivalence constant (see Table 1).

7.2. The Determination of the Protection Ratio for a General Offset

The visibility of the interference pattern is determined by the spacing between the stripes, measured along a line perpendicular to their direction. If this spacing is D', then

$$D' = D\cos\phi$$
$$= \frac{V_L}{F}\cos\phi$$

Now consider another wide offset F' that is equal to an integral multiple of the line-scan frequency, such that the spacing between its pattern stripes is also D'. The protection ratio required for this offset may be determined from Fig. 5. For this frequency:

$$D' = \frac{V_L}{F'}$$

hence
$$\frac{V_L}{F}\cos\phi = \frac{V_L}{F'}$$

or
$$F' = \frac{F}{\cos\phi}$$
$$= F\,.\,(1 + \tan^2\phi)^{\frac{1}{2}}$$

Substituting for $\tan\phi$ from Equation (7):

$$F' = F\left[1 + \left(\frac{E\delta F}{F}\right)^2\right]^{\frac{1}{2}} \qquad (8)$$

By using Equation (8) any general offset may be related to an equivalent offset having a value equal to a multiple of the line-scan frequency, whose protection ratio is already known. If necessary an allowance must be made for the change in the receiver response between the two frequencies.

If the $(E\delta F/F)^2$ term of Equation (8) is large compared with unity the interference pattern consists of a set of horizontal stripes (see Section 7.3). Under these circumstances Equation (8) should not be used to determine the protection ratio. Instead, the close-offset curves (Fig. 2) which refer to patterns of horizontal stripes should be used, taking the value of $|\delta F|$ given by Equation (6) as the abscissa value.

7.3. Maximum Offset at which Horizontal Patterns may be Obtained

All interference patterns in which the stripes are inclined at less than ten degrees to the horizontal may be classed as "horizontal patterns". Under these conditions:

$$\phi > 80^\circ$$

hence
$$\tan\phi > 5{\cdot}67$$

If the offset is greater than the nearest harmonic of the line-scan frequency, δF is positive and Equations (6) and (7) give:

$$\frac{E\delta F}{mf_L + \delta F} > 5{\cdot}67$$

therefore

$$\frac{mf_L}{\delta F} < \frac{E}{5{\cdot}67} - 1 \tag{9a}$$

If, on the other hand, the offset is less than the nearest harmonic of the line-scan frequency δF is negative and we obtain

$$\frac{mf_L}{|\delta F|} < \frac{E}{5{\cdot}67} + 1 \tag{9b}$$

In fact, the $E/5{\cdot}67$ term is much greater than unity and Equations (9a) and (9b) both reduce to:

$$\frac{mf_L}{|\delta F|} < \frac{E}{5{\cdot}67} \tag{10}$$

In order to enable three television transmitters to be mutually offset with equal reduction of the pattern visibility between any two of them, an offset differing by one-third of the line-scan frequency from the nearest harmonic of this frequency is used. It is of interest to find the highest offset at which horizontal patterns are produced when such a frequency relationship is used. In the case of a 405-line display, for example:

$$m < \frac{1}{3} \cdot \frac{304}{5{\cdot}67} \quad \text{from Equation (10)}$$

or

$$m < 17{\cdot}88$$

hence

$$m_{max} = 17$$

where m_{max} is the highest integral value of m for horizontal patterns.

The offset under these conditions is therefore:

$$17\frac{1}{3} \times \text{line-scan frequency}$$

$$= 175{\cdot}5 \text{ kc/s}$$

At this offset the value for the protection ratio indicated for an offset of 3·4 kc/s in Fig. 2 must be corrected by adding or subtracting 2 dB, depending on whether the interfering signal falls in the full- or vestigial-sideband portion of the receiver response respectively (see Fig. 4).

8. DERIVATION OF CLOSE-OFFSET CURVES FOR DIFFERENT DISPLAY FIELD-SCAN FREQUENCIES

Consider two television receivers which have different field-scan frequencies f_{F1} and f_{F2} and which are subject to interference having different close-offsets f_1 and f_2 respectively. Because the structure of the interference pattern depends on the relation between the offset and the nearest integral line-frequency value, it is convenient to consider offsets lower than half the lowest line-scan frequency involved. In this way ambiguities arising from any difference in the line-scan frequencies of the two displays are avoided. If it is assumed (see Section 1) that the interference patterns on the two displays will have equal visibility (and therefore that the same protection ratio will be required) when the number n of pattern stripes per field is the same in both cases, the offsets and the field-scan frequencies will be related, using Equation (1) of Section 3, by the expression

$$\frac{f_1}{f_2} = \frac{f_{F1}}{f_{F2}} \qquad (11)$$

The relationship shows that a close-offset protection-ratio curve for the American 525-line 60-fields-per-second display standard may be derived by obtaining a curve for a 525-line 50-fields-per-second display and then multiplying the frequency scale by a factor of 6/5. The result of this process is shown in Fig. 9.

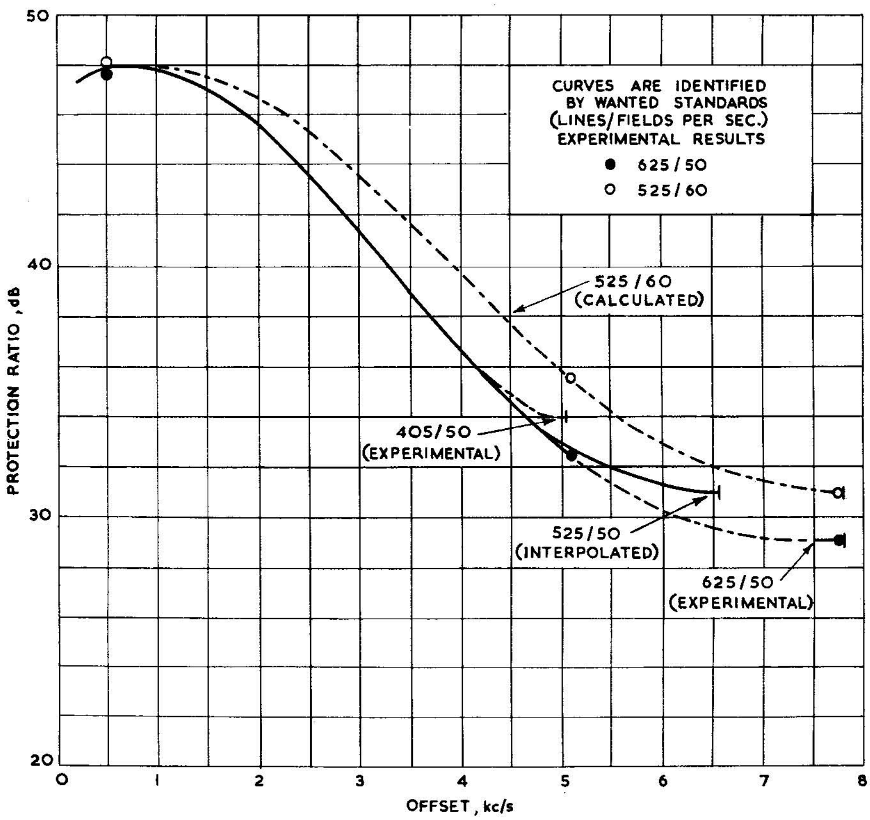

Fig. 9 - Close-offset protection ratios for C.W. interference to a 525-line 60 fields-per-second display

The curve for the 525-lines 50 fields-per-second standard was interpolated between the existing curves for the 405-lines and 625-lines systems (see Fig. 2); the error involved in this procedure was not thought to exceed 1 dB.

The difference in protection ratio required by the 525-line 60-fields-per-second and the 625-line 50 fields-per-second displays was determined experimentally for three offsets. A comparison technique was employed, the two receivers being viewed simultaneously. The ratio of the e.m.f.'s of the two signals supplied to the 625-line receiver was adjusted to the value given in Fig. 2 for each offset, and the ratio of the signals fed to the 525-line receiver was adjusted until a panel of observers judged the two interference patterns to be equally visible. These results are also shown in Fig. 9. It can be seen that they are in agreement with the derived curve for 525 lines, 60 fields per second.

9. CONCLUSIONS

Groups of offsets that give rise to interference patterns having the same spacing between successive stripes may be specified. Within each group the only difference between the various patterns will be the inclination of the stripes, and it may therefore be assumed that these patterns will have equal visibility. The relationships between the offsets in such groups may be derived; in particular, a relation may be found between a close offset giving a pattern of horizontal stripes, and a wide offset giving a pattern of vertical stripes, for a given display standard. This relation may be used to derive wide-offset protection-ratio curves from the experimentally obtained close-offset results, maximum pattern visibility conditions being assumed in each case. The experimental precision of the close-offset measurements may therefore be extended to include wide offsets. The upper frequency limit to which these wide-offset curves extend is set by the highest close offset which can be reliably used. This frequency limit is 1·4 Mc/s for a 405-line system, 2·2 Mc/s for a 625-line system and 2·9 Mc/s for an 819-line system. To obtain values of protection ratio for frequencies higher than these limits the curves may be extrapolated, but these values will become progressively less reliable as the frequency increases. At very high offsets the value of the protection ratio is determined by factors other than the visibility of the interference pattern. These wide-offset curves apply to monochrome transmissions and to receivers having "ideal" responses. They may if necessary be modified to take account of practical receiver characteristics, and extended to include interference to an NTSC-type colour transmission. The protection ratio required for an offset giving a pattern of inclined stripes may also be found.

By a similar method of analysis the effect of the display field-scan frequency on the close-offset protection-ratio relationship may be determined.

10. REFERENCES

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